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Abstract

More sophisticated and better controlled light, a key factor in environmental engineering, is discussed in three sections as follows--(1) how light should be released into interior spaces to satisfy the optical, physiological and psychological characteristics of people, (2) ways of reducing reflected glare, including the use of polarization, and (3) quality lighting at lower cost when lighting equipment with the fewest anti-footcandles is selected. (KK)

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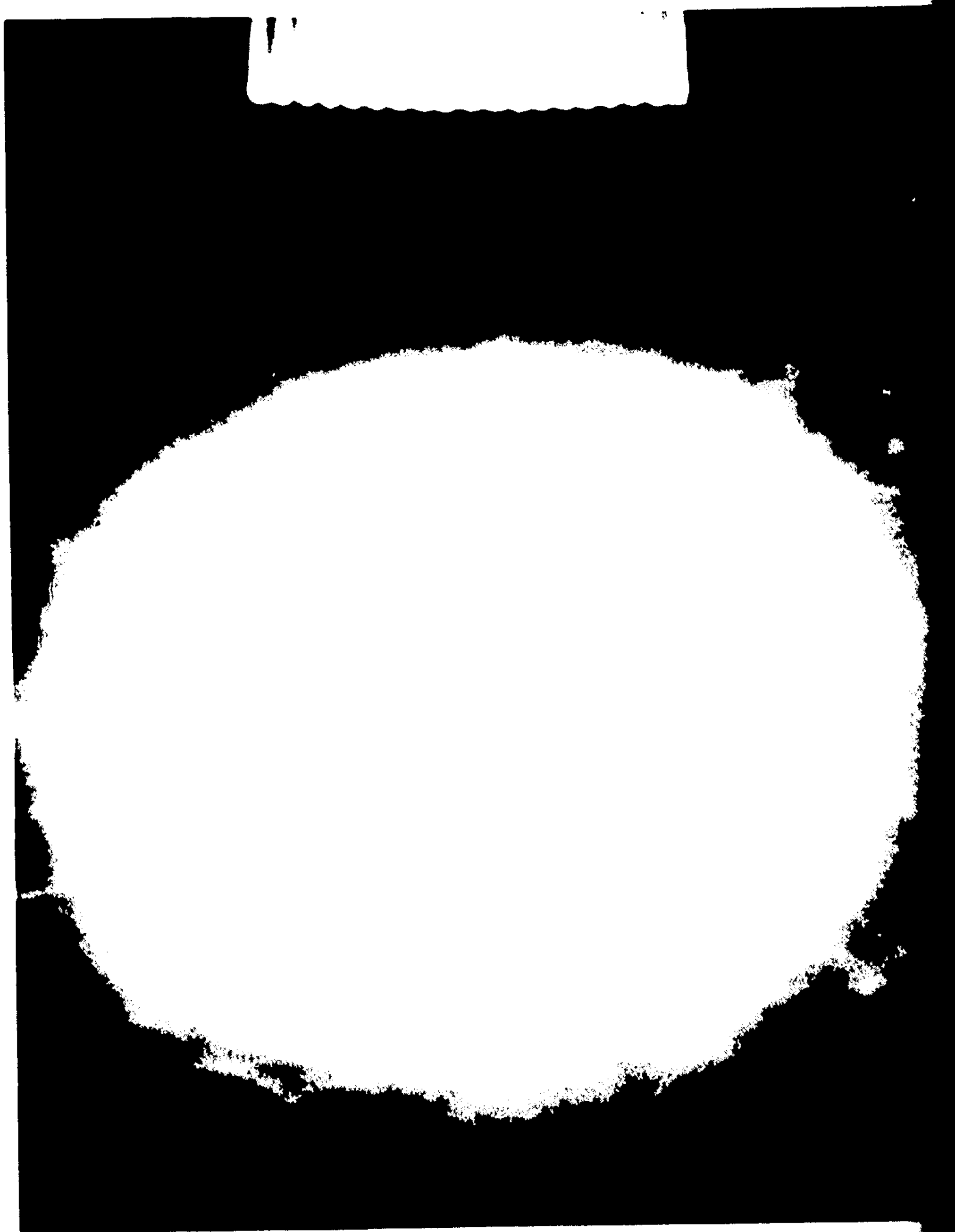
3 pamphlets
shot together

LIGHTING AND THE CONTROLLED ENVIRONMENT



Basic ray structure of a lens using accurately formed cones having the correct optic slope angles. Cone constructions vary greatly both in optical slopes and in patterns. (See fig. 3)

EF 002 699

Environmental Engineering is a rapidly growing discipline; its aim being to protect people more effectively against the hostile swings of nature, the hazards of living, and to conserve their health.

More sophisticated and better controlled light is a key factor in this development.

This issue discusses how light should be released into interior spaces to satisfy the optical, physiological and psychological characteristics of people. We make no apology for including data on the superiority of HOLOPHANE performance in these respects.

Henry L. Logan

Vice-President in Charge of Research

ED033535

LIGHTING IS FOR PEOPLE

LIGHTING IS FOR PEOPLE

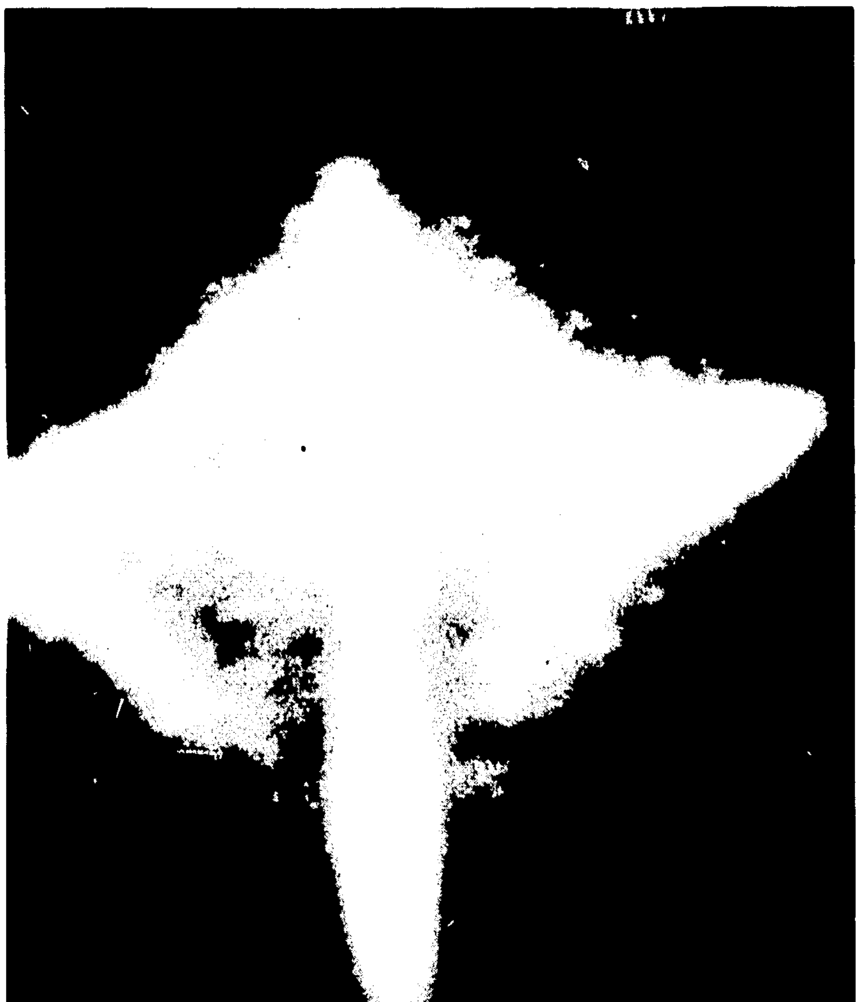
Just as buildings should be designed for people so should lighting. Part of the difficulty is that much artificial lighting is designed to be *looked at*. It is designed for buildings rather than people. Apropos of this an illuminating remark was made by Professor J. K. Page, Department of Architecture, University of Sheffield, when he complained that with modern low-brightness units the "walls were inadequately lit even when there was a high level of glare-free lighting on the working plane". This is a common complaint of those who feel lighting is for buildings rather than people. Incidentally, this effect of relatively dark walls *is always the result of dark finishes*, common in older buildings, and is not necessary to glare-free lighting.

There are fundamental differences between designing lighting for people, and lighting designed to fill an interior space with visual radiation. People have anatomical, physiological and psychological properties which buildings do not have. Lighting for people should be determined by these considerations, while not neglecting the architectural characteristics of the spaces in which they work and live.

First things come first. The welfare of the people who are otherwise "victims" of the lighting logically precedes other objectives. *It is a shift of emphasis*, which when fully understood, will lead to health-protecting and health extending buildings having an optimum favorable effect on the long-term behavior of the building occupants.

The recognition that lighting has a dominant role in establishing the optimum environment within a building comes slowly. A recent news report quotes a prominent "Architectural Advisor" as being "alarmed that lighting should be regarded as having a dominant role".

In practice light still waits to be treated as if it had a dominant role. Usually it is simply added to the other components of the building. It is the last one in and the first one cut; by then the money has begun to run out. This is especially true of schools: yet light is the one thing without which most buildings cannot be used. They can be used without heat. One can wear heavier clothing, as is done in many parts of the world. Air-conditioning is highly desirable, but not essential. One can perspire and still work; but one cannot work without light.



NO. 2 Basic ray structure of a "lens" using square pyramids.

BODILY BEHAVIOR

The importance of light to people will not be appreciated until its effects on people are better realized.

Radiation from both natural and artificial lighting puts photochemical and thermal energies into people, which have physiological effects. These give rise to psychological effects which are conditioned by the feeling state of the individual (emotional state), cultural attitudes and other higher functions which affect total bodily behavior.

This leaflet is too small to explain these effects. The best we can do is to list where they occur. Physiological effects occur in the eyes, the brain, the skin, the muscles and heart (motor system), the glands, (regulatory system), the blood vessels (circulatory system), the kidneys, the spinal cord, and in the rate of toxin build-up. When the dosage of the various components of the radiation is optimum, equilibrium is established between the demands of the environment on the body, and the internal functioning of the human system.

In view of this doesn't it make sense to design lighting to establish optimum internal equilibrium, with its beneficial effect on will to work, work performance, and health? If you agree, it is obvious lighting must be designed to fit the anatomical characteristics of people.

This means to fit it to the geometrics of the very special field of view of people; including fitting most favorably the viewing angles used most frequently.

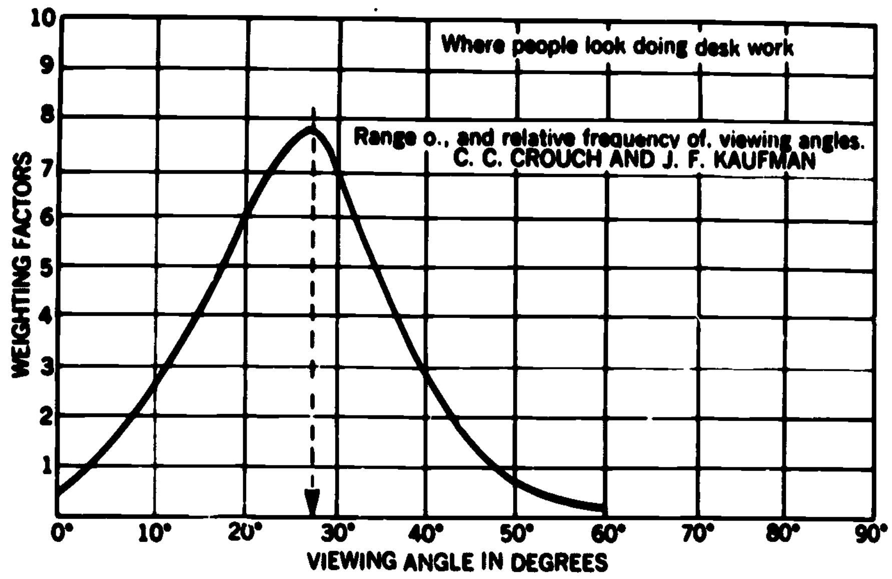
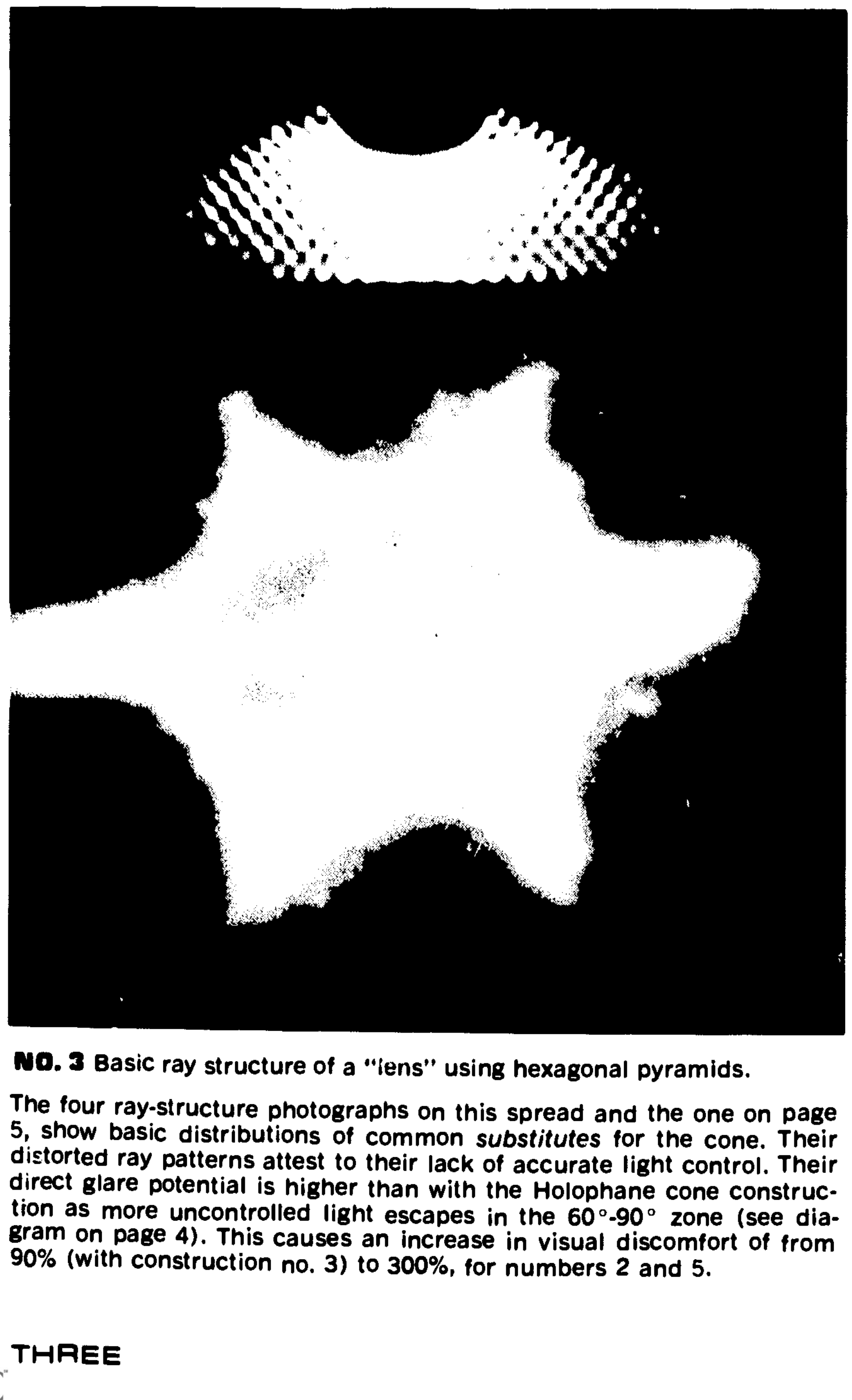
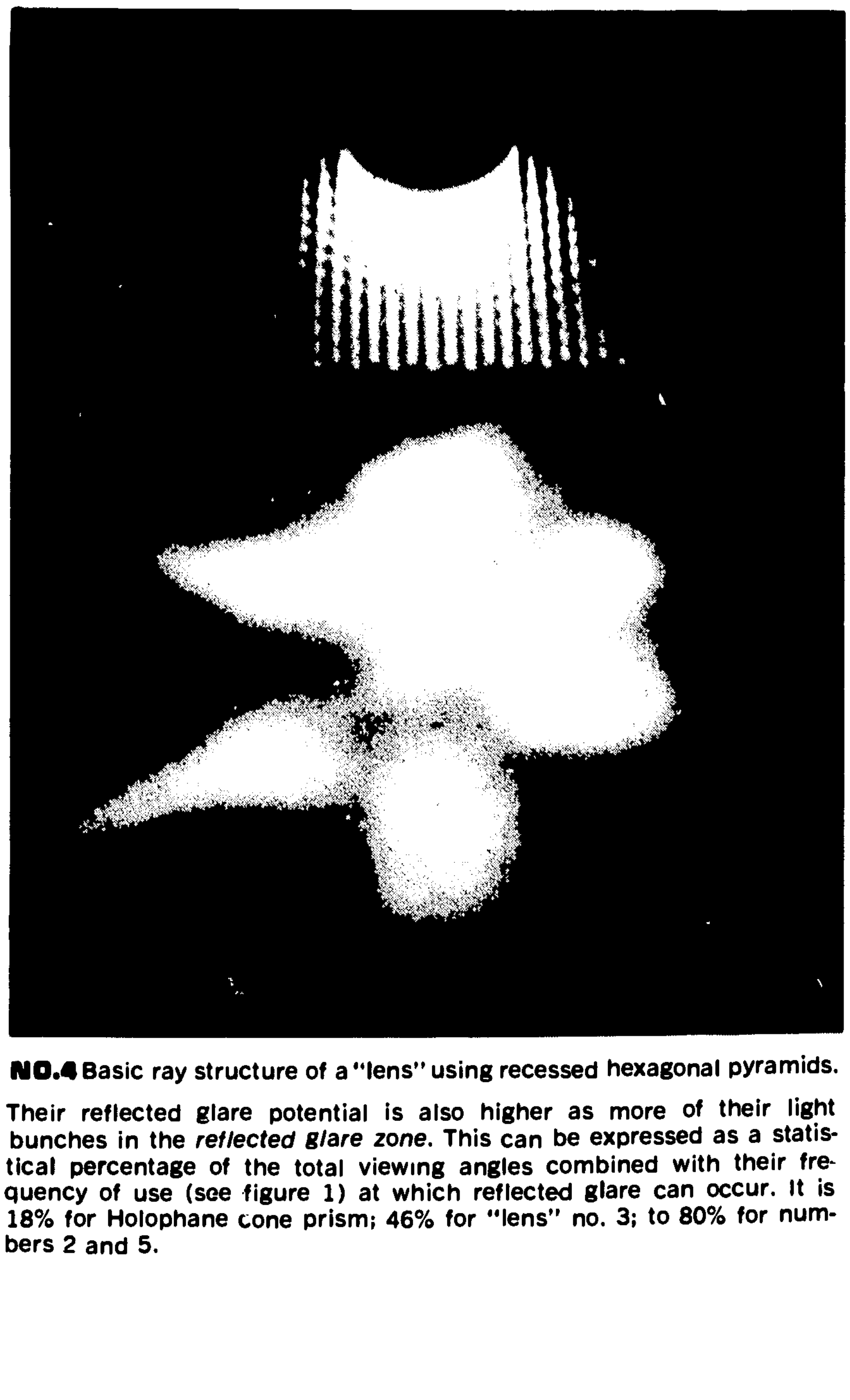


FIGURE 1



NO. 3 Basic ray structure of a "lens" using hexagonal pyramids.

The four ray-structure photographs on this spread and the one on page 5, show basic distributions of common *substitutes* for the cone. Their distorted ray patterns attest to their lack of accurate light control. Their direct glare potential is higher than with the Holophane cone construction as more uncontrolled light escapes in the 60°-90° zone (see diagram on page 4). This causes an increase in visual discomfort of from 90% (with construction no. 3) to 300%, for numbers 2 and 5.



NO.4 Basic ray structure of a "lens" using recessed hexagonal pyramids.

Their reflected glare potential is also higher as more of their light bunches in the *reflected glare zone*. This can be expressed as a statistical percentage of the total viewing angles combined with their frequency of use (see figure 1) at which reflected glare can occur. It is 18% for Holophane cone prism; 46% for "lens" no. 3; to 80% for numbers 2 and 5.

DIRECT AND REFLECTED GLARE

DIRECT GLARE

People face the field of view vertically. Glare straight ahead (like a bank of floodlights to hide scene-shifting on a stage), and up to 30° above the line of sight, is glare people cannot duck.

Light reaching people within these angles comes from the lighting system through the angles of 60° and 90° from the vertical. So this light must be reduced as much as possible. This means that the directions of the light rays must be controlled as they leave the lighting units. Just releasing light in space is not enough. It must be released in carefully tailored proportions through different angular zones in order to co-operate with man's visual and anatomical characteristics.

OPTIMUM DAYLIGHT—THE MODEL

Daylight scenes with a visual comfort rating of over 75% are clear blue skies with the sun overhead, lighting a piece of white paper to 3500 footlamberts or better, but with the brightness of the sky facing the observer only 500 footlamberts (1/7th of the illumination). Many artificial lighting units which light a piece of white paper to only 70 footlamberts, will have an average brightness towards the observer in the 60° to 90° zone, of 500 footlamberts (seven times the illumination). Few people realize how sharply controlled is optimum daylight—the light to which we are best adapted: and which must serve as our model for optimum artificial lighting.

NO. 5 Basic ray structure of a "lens" using recessed square pyramids.

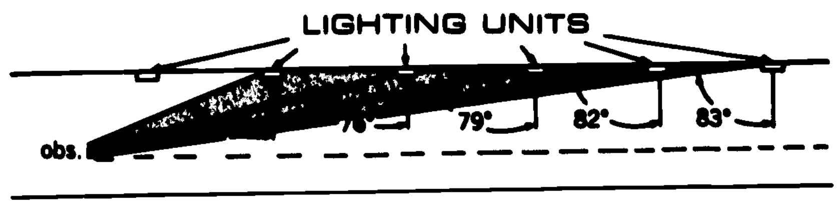


Diagram showing glare light directions in typical office. From positions of lights it is rays sent 60° to 90° from the vertical. These rays the observer receives 30° or less above his horizontal line of sight.

REFLECTED GLARE

Reflected glare is also related to the anatomical characteristics of man. The most comfortable, and so the most frequently used visual angle at which people look at desk work is 27° from the vertical (see Fig. 1). This means that if the preponderant light from a lighting system is around 27° from the vertical reflected glare will be at a maximum. Therefore, the anatomical characteristics of people require control of the direction of the light rays to avoid "bunching up" in the reflected glare zone, as well as in the direct glare zone.

EVALUATING LENS PERFORMANCE

It is easy to separate the "sheep from the goats". Just shine a narrow beam flashlight through a lens and notice the characteristic pattern. Compare with pictures in this issue. The best basic pattern is obviously that shown in the cover picture. If it had a mean ray direction of 27° it would cause reflected glare—but it doesn't). The spread of the pattern affects only 18% of the view-frequency conditions met with in desk work; compared to 46% for the next best pattern.

As a quick test the flashlight beam is sufficient, where competitive patterns vary as widely as shown in this leaflet. Where several products with an apparently similar ray structure are offered it is necessary to dig deeper.

Figure 2, page 5, shows the photometric distribution of one of our lenses and a substitute. These slightly different curves look practically the same.

The difference in the critical glare zone (60°-90°), is barely visible even when carefully drawn. It could easily be hidden in the thickness of carelessly drawn lines. It only amounts to 1.5% of the total output; yet this small photometric difference is a huge difference to the eye which does not use a photometric scale. *It causes a 94% increase in glare response!*

The practical effect is that the substitute would need a 75% increase in light from non-glare directions to equal the visual comfort performance of our lens. The small price savings that may exist between the lens and the substitute would be wiped out several times over.

RAY STRUCTURE

RAY STRUCTURE

So that we can get a clearer idea of the basic importance of the ray-structure of the light released into visual space, let us recall that with some light we see a little; with much light we see a lot: which is why the lighting industry has been talking footcandles for the last fifty years.

During this time the realization has grown that mere quantity of footcandles, as measured by a meter, is not the whole answer: and the word "quality" (which really means the right ray-structure), has come into use to label the other factors.

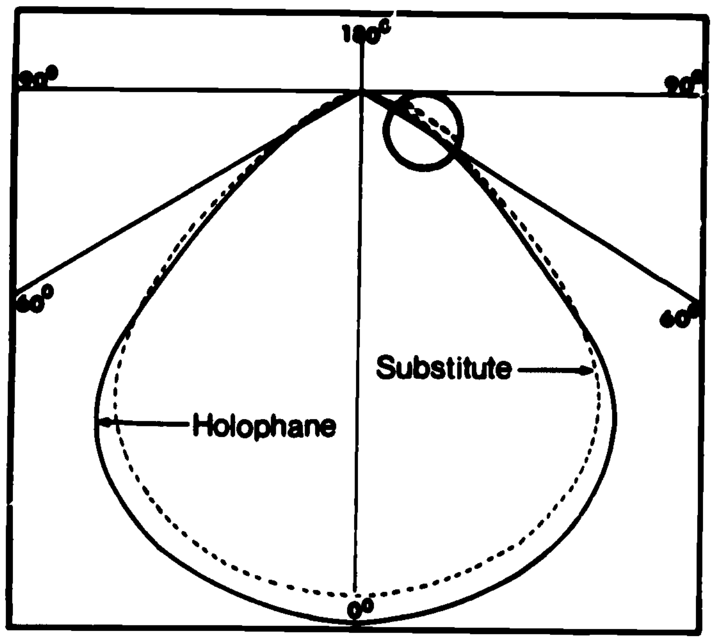


FIGURE 2

TEST Nos. 19166-A and 19167

The output difference between the Holophane lens and the substitute above in the critical 60°-90° zone is 1.5%, but it causes a 94% increase in direct glare response for the substitute lens.

NO. 6 Basic ray structure of a "lens" using longitudinal ridges.

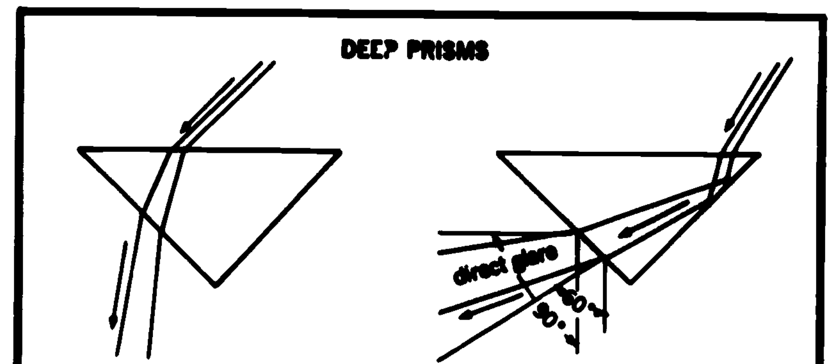


FIGURE 3

This is why one footcandle from a good Holophane CONTROLENS installation causes higher visibliity than footcandles that do not have the ray-structure of a CONTROLENS footcandle.

ALL FOOTCANDLES ARE NOT ALIKE

It is now clear that all footcandles are not alike. They all add up the same way on the meter, but they don't all add up in the eye. Some subtract.

High quality lighting includes less of the subtractive footcandles. So, although footcandles are still fundamental the emphasis is changing to *the kind of footcandles which are most helpful for people.*

A recent scientific paper (May, 1965), points out that "Good lighting now depends less upon the absolute value of illumination on the working plane and more upon the distribution of the light on the work and in the general environment"; that is, it depends upon the *precise ray-structure of the light.*

SHORT-COMING OF METERS

Meters cannot discriminate between footcandles. Meters are not (for the purposes of this discussion), sensitive to the *direction from which the footcandles come;* while the eye is. The eye is so sensitive to direction that, when footcandles come from some directions they cause the painful sensation of direct glare; while when they come from other directions they can conceal, instead of reveal, what they fall on—reflected glare!

There is one practical way of reducing these wrong-direction footcandles, namely, *controlling the directions in which light rays are permitted to enter the field of view.*

When this is done correctly it adequately reduces both direct and reflected glare; but to do it correctly requires a sharp arrangement and micro-control of the ray structure.

HOLOPHANE CONTROLENS® VERSUS COMPETITION

The evidence that this is accomplished by Holophane lenses is given in this issue: but there is more to it. Lighting systems are more than the summation of the properties of INDIVIDUAL lighting units. The properties of the space lighted have to be taken into account. This is because the eyes operate only on relative differences in brightness between one feature of a visual pattern and others (not on absolute quantities of light). This makes slight differences important, and requires control of the environmental finishes. We offer architects expert help on this.

Not until the professional advisers of the light-using public understand the importance of control of the micro-ray structure of the emitted light, in combination with control of environmental finishes, in providing optimum lighting for an optimum environment, will substitutes be rejected. Substitutes are now accepted for their price tag in the absence of the necessary specialized knowledge.

PENALTIES FOR NEGLECT OF RAY STRUCTURE

That the acceptance of such substitutes may result in severe penalties is shown by a study we recently conducted of a standard classroom with six different lighting methods. All systems were designed to deliver 85 footcandles. The direct and reflected glare of each system was determined. As all the figures were higher than for the Holophane system it was set at unity, and the *extra footcandles* determined which each system would need, for its direct and reflected glare to be reduced to the same figures as for the Holophane lens system. The figures are:

FOOTCANDLES

	Holophane	A	B	C	D	E
Direct Glare	85	+8	+24	+72	+134	+165
Reflected Glare	85	+8	+10	+21	+ 34	+ 36

The figures show a wide variation in performance between systems considered by many as "or equal". They show the economic penalties for substitution to run from 9% to 94%. That is the variation in extra cost to bring the various systems to the same level of low-glare performance as the Holophane system.

QUESTIONS AND ANSWERS

Lighting technology is advancing in depth and unavoidable complexity, just as is every other facet of our modern technological society. We may yearn for the return of a simpler age but it has gone forever. We have tried to make this issue understandable to the ordinarily knowledgeable reader, and we hope we have succeeded. We welcome questions aimed at clearing up points obscure to any reader. If enough come in we will publish the questions and answers in a subsequent issue for the benefit of all.

EVALUATION STUDIES INVITED

Specific analyses, with all supporting data, of the direct and reflected glare performance to be expected, can be made for your lighting projects. This will permit you to decide in the "light" of full information, instead of in the dark.

Please do not hesitate to send us your requests for this helpful data on your important environmental controlled lighting jobs.

HOLOPHANE COMPANY, INC.

1120 Avenue of the Americas, New York, N. Y. 10036

Holophane Trade Mark

Lighting Authorities Since 1898

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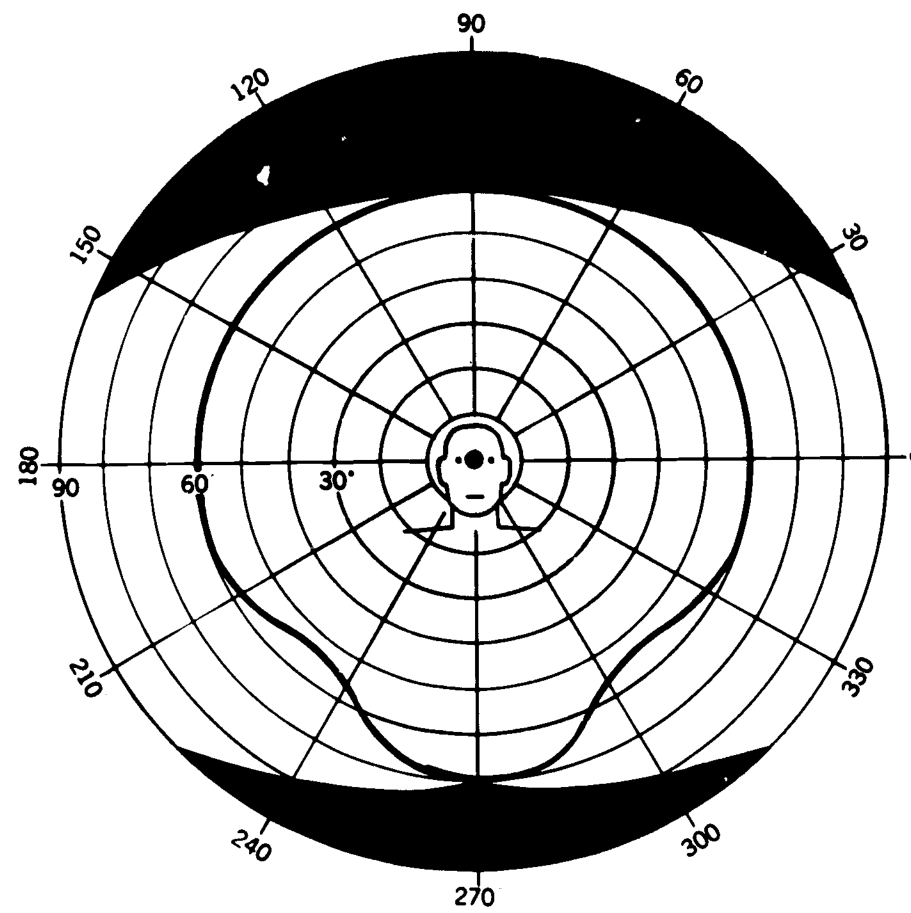


Small degree radius – acute perception

30 radius – accurate comprehension and direct glare zone

60 top and side – 70 down – comprehension

60 to 90 – peripheral range

Cut-off of Visual Field by Eye Sockets

REFLECTED GLARE: SOLUTIONS

Illumineering

REFLECTED GLARE

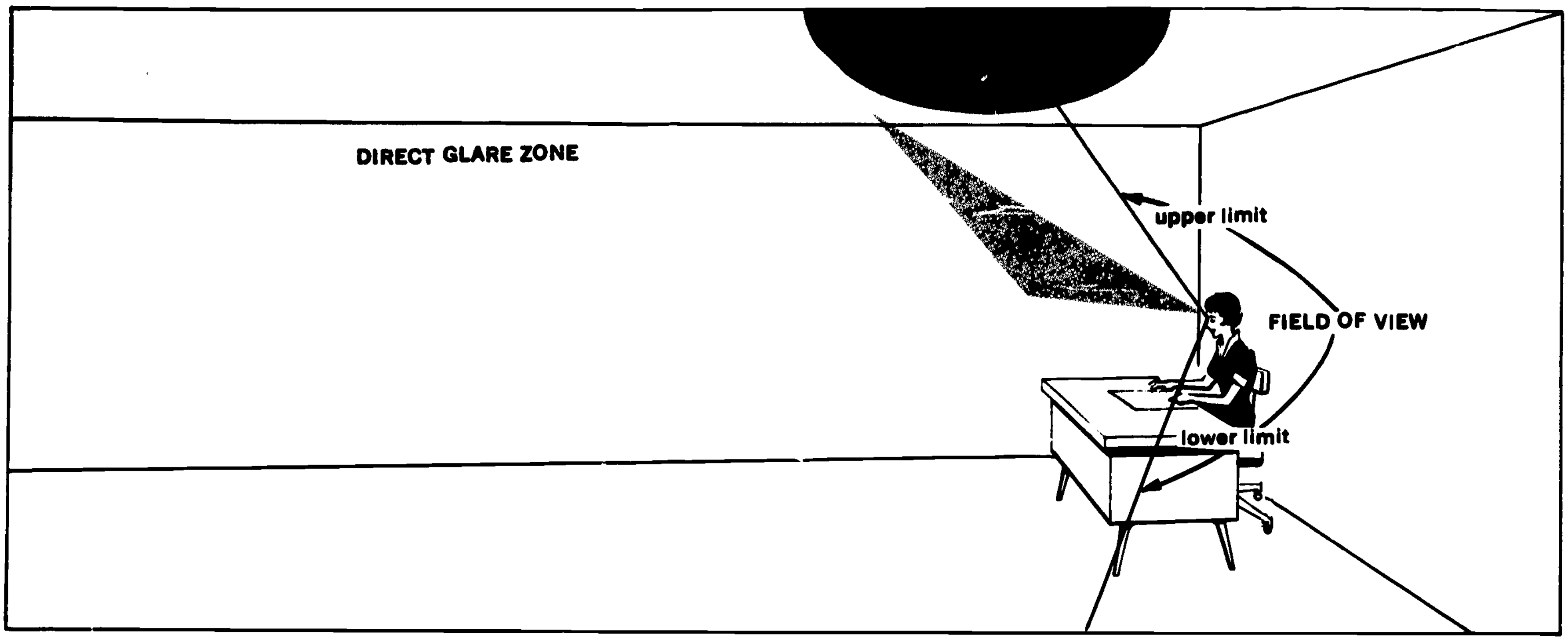


FIGURE 2 GEOMETRY OF THE FIELD OF VIEW. DIRECT AND REFLECTED GLARE ZONES. From the observer's position.

REFLECTED GLARE

Reflected glare is really a simple subject. It has been confused by the piling up of more and more data about less and less. Demagogues are not the only people who are skillful in inventing the right solutions for the wrong problems.

Let us look into this.

KINDS OF REFLECTED GLARE

There are several varieties: (1) SPECULAR REFLECTION—mirror-like images in polished surfaces. (THESE ARE OBVIOUS). (2) SPREAD REFLECTION—distorted spread images in semi-matte surfaces. (ALSO OBVIOUS). (3) VEILING REFLECTIONS—a localised reduction in contrasts on apparently matte materials (NOT OBVIOUS; but does reduce ability to see). (4) GENERAL REDUCTION IN CONTRASTS ALL OVER THE FIELD OF VIEW. This has the same effect as a very thin mist would have. It occurs to the greatest degree with highly diffused general lighting.

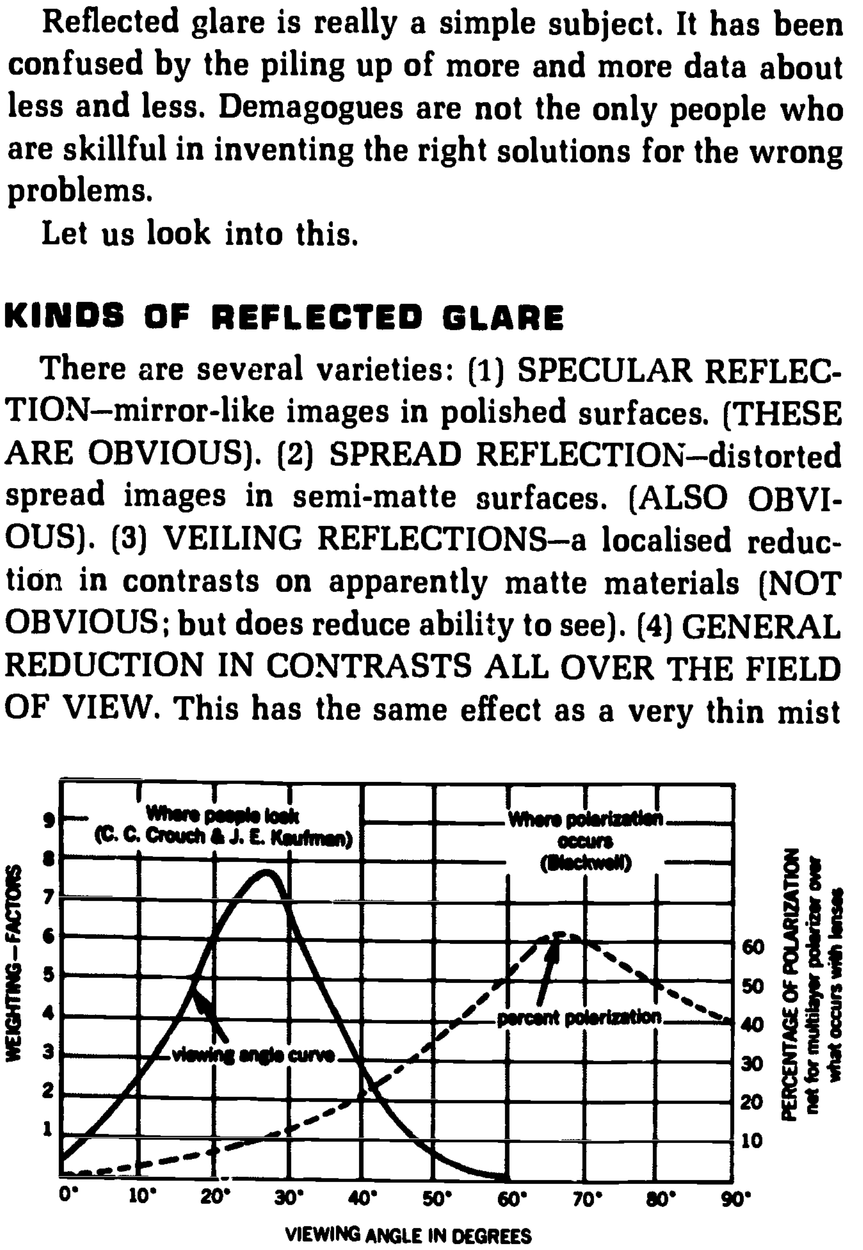


FIGURE 1

TYPE 3 GLARE

All the publicity of recent years has revolved around type (3)—localised veiling reflections.

The basic data published has concerned the visibility properties of pencil marks on paper—principally the properties of a "period", or small dot. A tremendous amount of material has been derived from measurements or computations (mostly the latter) of the pencilled "dot". As a result we now know a great deal about the "dot". Attempts to relate this data to other target shapes, specifically pencil handwriting, has resulted in further experimental work now underway.

THIS WORK HAS HAD THE MERIT OF CALLING ATTENTION MORE SHARPLY TO VEILING REFLECTIONS, AND HAS STIMULATED EFFORTS TO COMBAT THEM.

THE PROBLEM

The key to understanding this matter is to understand the problem. The problem investigated is not the commonsense, broad problem posed by veiling reflections, which the reader would naturally expect (and might infer from propaganda). It is the rather narrow problem of how to light *pencil writing* on horizontal, electrically insulating materials, on flat desks, at the viewing angles used by desk workers, so as to materially reduce, if not eliminate, veiling reflection. Pencil writing is an essential limitation to the problem as all the scientific data is based on it. It does not apply to ink writing which stains

SOLUTIONS

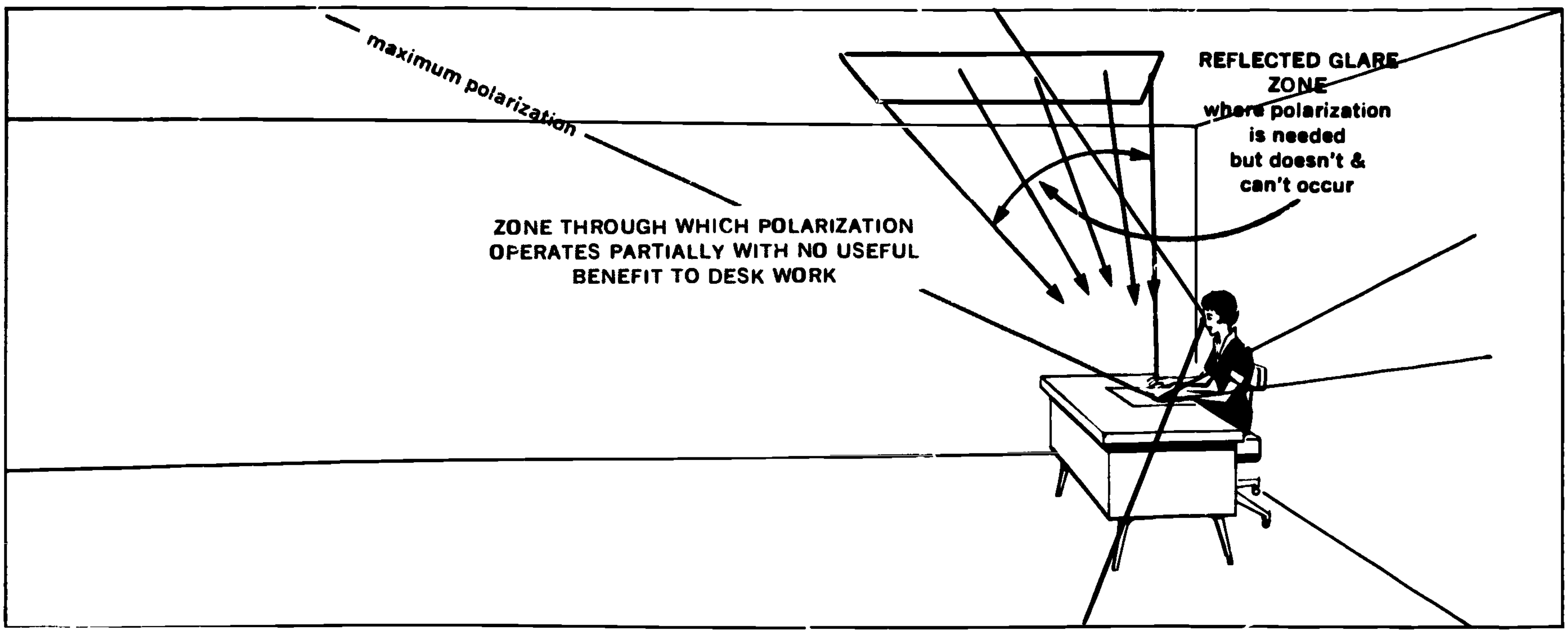


FIGURE 3 GEOMETRY OF POLARIZATION FROM THE POSITION OF THE OBSERVER

the fibers of the materials it is written on, and which is often made relatively darker by veiling reflection from the background and therefore easier to see.

A pertinent question at this point is, why should the work have been spent on pencil writing (actually a pencilled "dot"), when pencil work is so relatively unimportant under modern studying and working conditions? The reasons given are that pencil writing is claimed to be a large part of classroom and office work; and the visibility of pencil writing can suffer greatly from localised veiling reflection.

SOLUTIONS

There are two kinds of ways to reduce localised veiling reflections as far as light falling on pencil writing is concerned: practical ways and a "theoretical" way.

One practical way is to arrange the work and the lighting units so that the working locations are outside the potential reflected glare zones of the lighting units. This is illustrated by Fig. 5 and Fig. 7, and can be done more often than many people realize.

A second practical way is to optically control the directions at which light is emitted from the lighting units, so that (1) the lamp "image" is spread widely on the lens (reducing its potential reflected brightness) (see Figure 8). (2) the light in the reflected glare zone issuing from the unit is balanced with the light issuing in other directions, to reduce reflected glare, and a co-operative spacing of units is adopted to flood the work with light from non-reflecting glare-angles.

The "theoretical" way—polarization—is the answer to the wrong problem mentioned in our first paragraph.

POLARIZATION

Polarization solves the problem "When the objects to be lighted are horizontal, electrically insulating and viewed at angles larger than 50 degrees off the vertical": but this is NOT the problem presented by flat desk work.

VIEWING ANGLES (AND SOLUTIONS)

A curve showing the relative frequency of the various viewing angles used by desk workers is given in Fig. 1. On this same graph is a curve showing the percentage of polarization which occurs with good multilayer polarizers at all angles from the vertical from 0° to 90°. For polarization to be effective for flat desk work the two curves should lie one on top of the other, or at least, should largely overlap. Instead they are almost entirely out of phase.

The most frequently used viewing angles cluster around 25° from the vertical, as can be seen by inspecting Fig. 1. Dr. Blackwell told the Illuminating Engineering Society, "RQQ" Committee on Feb. 5, 1962, in referring to where polarization was beneficial, "Forget reflected glare at 25°*! You can't do anything about it with any luminous materials; but you can do something about it by arrangement of light sources, and light control"; that is, the effective solutions are the "practical" answers given above under "SOLUTIONS".

This is confirmed by the report of the RQQ Committee, (pg. 562, Illum. Eng., 1962) that the answers to the reflected glare problem are: "When the worker's location

*Statement by IES, RQQ Subcom., on REFLECTED GLARE, June 13, 1962, "Dr. Blackwell . . . . shows that none of the materials has appreciable overall effectiveness at 25°".

POLARIZATION

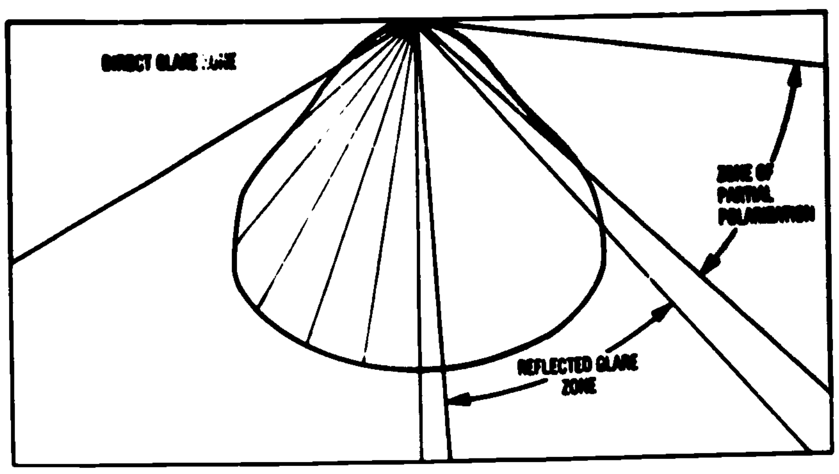


FIGURE 4 GEOMETRY OF THE THREE ZONES (direct glare, reflected glare and the zone of partial polarization) AS SEEN AT THE LIGHTING UNIT.

can be fixed, lay out the lighting so luminaires do not cause veiling reflections"; and, "In the general case, lower contrast losses will occur as more luminaires or greater lighted ceiling areas are used". Their concluding sentence is, "wise choice of lighting media and systems for a given situation must still depend on careful analysis of the seeing task; creation of a pleasing environment; and recognition of efficiency, economics, appearance and maintenance". This is what we in the Holophane Company try to do to the best of our ability.

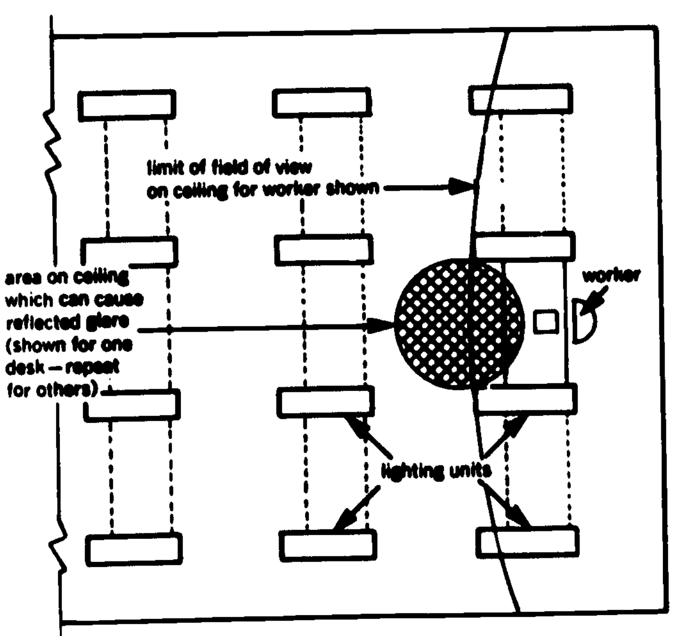
OTHER LIMITATIONS OF POLARIZATION

Drafting tables are usually inclined. So are a large percentage of school desks. Goodbar showed, (Illum. Eng., April 1964, p. 13A) that "when tasks are not horizontal and are instead, * * tilted, polarization may not only not help at all, but on the contrary, it may increase the contrast losses as compared with unpolarized light".

When the tasks are electrically conductive, such as bright metal-like surfaces, polarization is absolutely ineffective. Any expense incurred to produce it (including the inescapable light losses) is, without any question, thrown away.

As the polarization effect is largely caused by absorption of light vibrating in unwanted planes, the output efficiency of multilayer polarizers relative to lens units depending on optical control, is lower. That is, they deliver less light per watt. Some of this reduction occurs in the direct glare zone, but it is less than the reduction accomplished by optical control. That is, multilayer polarizers also generate more direct glare, as well as less light. The offset claimed is that the less light is more visually effective. As we have seen, this claim is not true for FLAT DESK WORK.

The extent of claimed visibility gain (if it could be taken advantage of for flat desk work), is stated in terms of the extra footcandles needed to compensate. It is significant that the extra footcandles needed to compensate for the increased DIRECT GLARE of multilayer polarizers is considerably more than can be theoretically saved by the potential reduction of reflected glare. In a typical classroom for example, using the same wattage and the same number of lighting units, when a lens system delivers 70 footcandles a multilayer polarizer system will deliver 49. At the actual viewing angles used in classroom work its polarizing component does not come into play, and it delivers slightly more reflected glare; sufficient to require its level to be raised from 49 footcandles to 78 footcandles, compared to 70 for the lens system; but its direct glare is sufficiently greater to require its level to be raised by additional glareless light to 90 footcandles. That is, the compensation for its increased reflected glare is 29 footcandles, but for its increased direct glare is 41 footcandles. The non-benefits of polarization for flat desk work are achieved by a process which is akin to burning your house down to cook your dinner.



PLAN
10' CEILING

FIGURE 5 Showing how potential reflected glare can be avoided. Principle: never locate a lighting unit over a desk in the crosshatched area.

THE GEOMETRICS OF THE FIELD OF VIEW

We hope it is now clear from all the preceding that the introduction of polarization for flat, or tilted desk work, has only confused an otherwise simple matter. When and where it is desirable to minimize reflected glare, not only on desk work but generally, the answer lies in designing lighting to fit the geometrics of the special field of view of people, emphasized in our last issue.

This is not meant to imply that polarization is ineffective per se. On the contrary, when it is applied as defined under "POLARIZATION", page 3 of this issue, it can be

GEOMETRICS: FIELD OF VIEW

spectacularly effective: but for flat or tilted desk work, or for electrically conducting surfaces, it can be a costly misapplication.

The special field of view of people is illustrated by the spherical perspective diagram on the front cover. The most important part is the central area colored light blue. Excessive brightnesses in this part of the field of view (usually lighting units on the ceiling) cause direct glare. The reflected glare zone is not shown on this diagram because it partly originates outside the field of view.

The geometrics of both the direct glare zone, and of the reflected zone are shown in Fig. 2 as they appear to an observer. They are also shown in Fig. 4 as they appear on emerging from the lighting unit.

REFLECTED GLARE ZONE

The observer can only get localised veiling reflection from that portion of the field of view which is immediately ahead and above him. This has been determined to be a forward tilted, upside-down cone, with its apex on the work, its axis 25° from the vertical, and its width 43.5°.

This is illustrated by Fig. 3, where it can be graphically seen that the zone through which polarization partially operates is outside the reflected glare zone (when it should be in it), and in fact, corresponds more closely to the direct glare zone (compare with direct glare zone location in Fig. 2 and 4). This diagram (Fig. 3) also shows that the polarized light reflected from the work is at angles far below the head of the observer, where it cannot be seen.

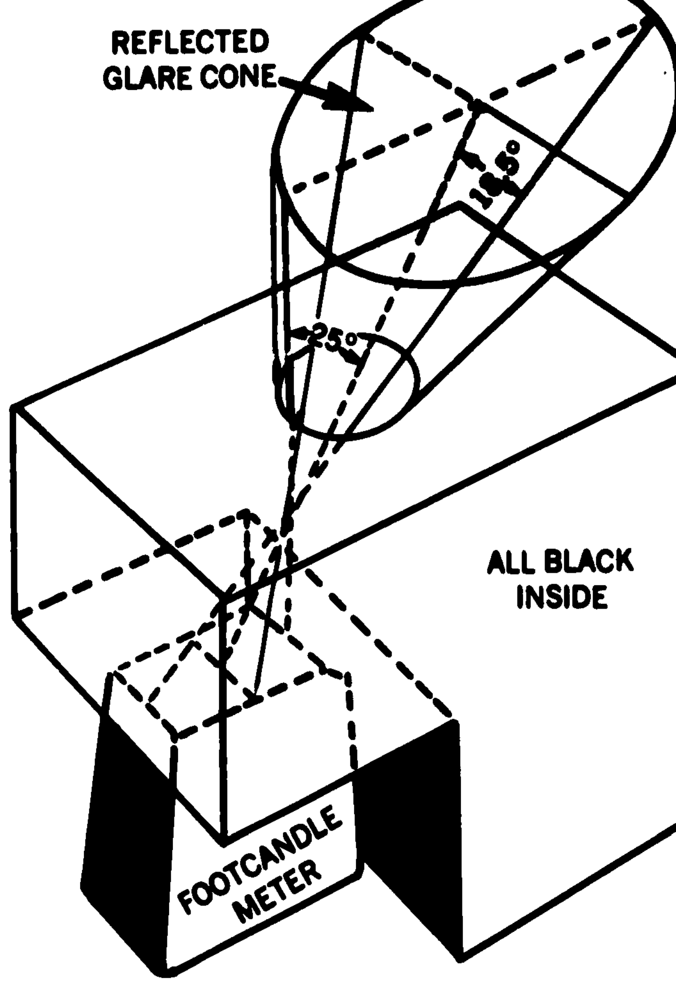


FIGURE 6 DeLANEY POTENTIAL VEILING REFLECTION METER

MEASUREMENTS: POTENTIAL VEILING REFLECTION

POTENTIAL VEILING REFLECTION

It is obvious that the potential veiling reflection in a visual scene is a function of the amount of light falling on the work from the reflected glare zone, in relation to its proportion of the total light falling on the work. For example, if the illumination on the work is 100 footcandles, and the light from the reflected glare zone is 10 footcandles, the light which could cause reflected glare is 10% of the total. If another lighting system was considered, which also delivered 100 footcandles on the work, of which only 6 footcandles was from the reflected glare zone, the latter would have proportionately lower potential veiling glare. This is a simple way by which the relative reflected glare of alternative solutions to a lighting problem can be determined.

A device (see Fig. 6,) has been developed by W. B. DeLaney of the General Electric Company which uses a footcandle meter which will measure, in the field, the percentage of potential reflected glare light as compared with total light.

The kind of data you get with it is shown in Fig. 7. The measurements of overcast and blue sky, and diffusing ceiling were made by Mr. DeLaney. They serve as yardsticks for other kinds of lighting. This simple method *shortcuts* all the COMPLEX MEASUREMENTS AND COMPUTATIONS which abound in recent technical lighting literature. It does not show the actual veiling reflection, but the *relative propensity* of different lighting systems to generate it, which is all the lighting user needs to know.

This determination can also be predicted, with as good accuracy as footcandles can be predicted, from the architect's drawings of the space. The procedure is simply a variation of the method by which we now quanti-

MEASUREMENTS: POTENTIAL VEILING REFLECTION

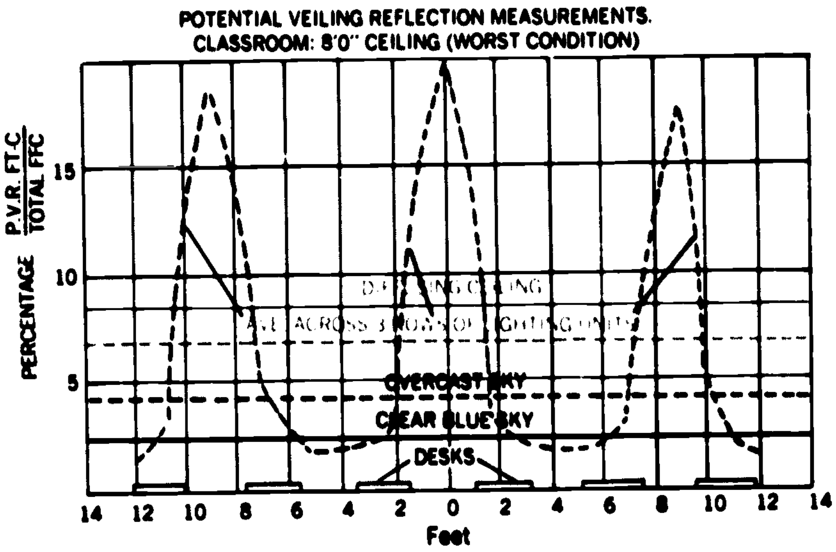


FIGURE 7 Normal desk locations shown: the maximum *potential* veiling reflection from 3 rows of lighting units occurs over the aisles: on children's desks it is near the minimum which occurs with natural lighting.

FIGURE 8 Superior lamp obscuration property of Holophane injection molded lens (bottom) provides more uniform luminaire appearance and reduces reflected glare effects.

tatively predict direct glare; and we are prepared to furnish architects and engineers this engineering data for their jobs, from their drawings, on request.

Returning to Fig. 3 it is clear that to reduce potential veiling reflection the light in the reflected glare zone issuing from the unit must be so controlled in quantity in specific directions, that when the units are installed as a well-planned system, the combination of proportionately less light at the most frequently used viewing angles, and of co-operative arrangement of lighting units which will flood the work at non-reflecting glare-angles, will result in the lowest potential veiling reflection.* That Holophane lens equipment has this kind of ray control was clearly established in our last issue. (See ARCHITEXTS, No. 1, 1965).

**Footnote*

Reflected glare, when it occurs (and it is less widespread than propagandists would have us believe) is caused, as we have pointed out, by the lighting units or luminous ceiling, directly in front of observer's position. It is therefore most obvious with one light in a small office. As soon as two or more are put in the reflected glare reduces.

In a large general office, or even a classroom where sufficient lighting units can contribute to every point on the working planes, the reflected glare from the offending unit tends to be overwhelmed by the contributions of the other units, which all come at angles that cannot cause reflected glare at the observer's position.

Architects and engineers can therefore safely rely on getting minimum reflected glare, as well as minimum direct glare when they design and specify a well-planned Holophane lighting system. Again, we offer the facilities of our field engineers, and of our headquarters department of Applied Engineering, to aid them in getting the best possible results for the people who will occupy and work in their structures.

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Lighting Authorities Since 1898

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LIGHTING AND THE CONTROLLED ENVIRONMENT

QUALITY LIGHTING FOR YOUR CLIENTS AT LOWER TRUE COST

ANTI-FOOTCANDLES

PURPOSE OF LIGHTING

The purpose of lighting is to reveal visual information. We gain access to the outside world by the discernment of shape, color and contrast. The more clearly we can discern shape, color and contrast the more information do we glean from a particular scene.

When we spend money for a lighting system we spend it to gain the maximum visual information our money will buy.

GLARE is useless light. It gives no useful information. In addition, it hides visual information otherwise available. Money spent on lighting systems which produce glare is money partly, sometimes largely, wasted.

Just as sonic "noise" interferes with music or speech reception, so visual "noise" (anti-footcandles) interferes with the receipt of visual information and intelligence.

As sonic "noise" is overcome by increasing the power of the sound over the background noise, visual "noise" is overcome by increasing the power of the footcandles over the anti-footcandles. The cost of the extra footcandles needed is the measure of the economic loss caused by glare.

HOW THE COST OF GLARE IS FOUND

To find out how many extra footcandles are needed it is necessary to go beyond current ways of using photometric data. Glare is not only an effect of the brightness of the lighting units ("B"), but also the position of the units in an installation ("P"), their size ("Q"), plus, "a" which is a value depending upon the number of light sources, and the lighting level to which peoples' eyes are adapted ("F") in a particular room, with its special size, shape and finish.

The formula, which expresses the scientifically determined connections between the above factors for a single lighting unit is:

SENSATION (M) $= \frac{BQ}{PF^{0.44}}$; and for a system of units

is: $\left(\text{Sum of all } \frac{BQ}{PF^{0.44}}\right)^{a}$

With this formula a tool now exists with which your expert advisors can determine the true economic differences between luminaires offered as "or equal".

This is because the formula permits us to find the total footcandles at the eyes ("F"), needed by more glaring systems to equate to the least glaring.

For example—Let us evaluate three typical classroom lighting systems.

The layout for each is three rows of five units each: and the "vital statistics" are in the table below.

SPACE DATA: WIDTH 24', LENGTH 30', CEILING 9'.

Competing Prismatic Lens Systems	NO. OF UNITS	LAMPS	C.U.	fc	F fL	AVERAGE BRIGHTNESS		
A	15 4' x 1' Flush	30 40/RS 3100 lu.	0.53	69	25	60° 930	70° 675	80° 590
B	Same	Same	0.57	74	27	600	435	460
C	Same	Same	0.62	80	38	435	350	415

While the layout for each of the systems is identical, the photometric data for the components (units) of each of the systems is slightly different, and the prices are different.

OR EQUAL

The components are of the type which architects and engineers usually accept as "or equal" on the basis of their photometric distributions and their mechanical quality.

Photometric data are usually visually inspected. If the curves look reasonably similar, and the figures are in the same "ballpark", they are accepted as "or equal".

Look at the curves in Figure 1. There is not much apparent difference. When superimposed and shown on the larger scale of Figure 2, some differences emerge. Even so, the architect or engineer is likely to be more impressed by the differences below 45° which are of minor importance.

The much smaller differences above 45° principally account for the differences which occur in the effect of the lighting on people using these three lighting systems.

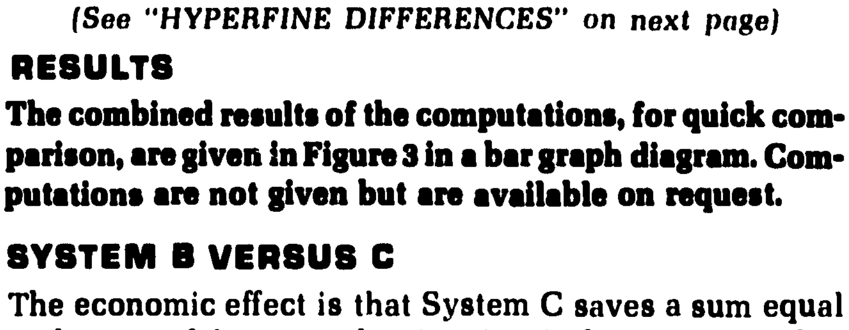


FIGURE I Three Distributions accepted as "Or Equal" by many architects and engineers.

(See "HYPERFINE DIFFERENCES" on next page)

RESULTS

The combined results of the computations, for quick comparison, are given in Figure 3 in a bar graph diagram. Computations are not given but are available on request.

SYSTEM B VERSUS C

The economic effect is that System C saves a sum equal to the cost of dropping the glare level of System B to that of C.

This can be conservatively estimated by dividing the lighting level needed by System B by the lighting level it delivers: i.e., $\frac{102}{74} = 1.38$: so the percentage of "plus"

"OR EQUAL" VS HYPERFINE DIFFERENCES

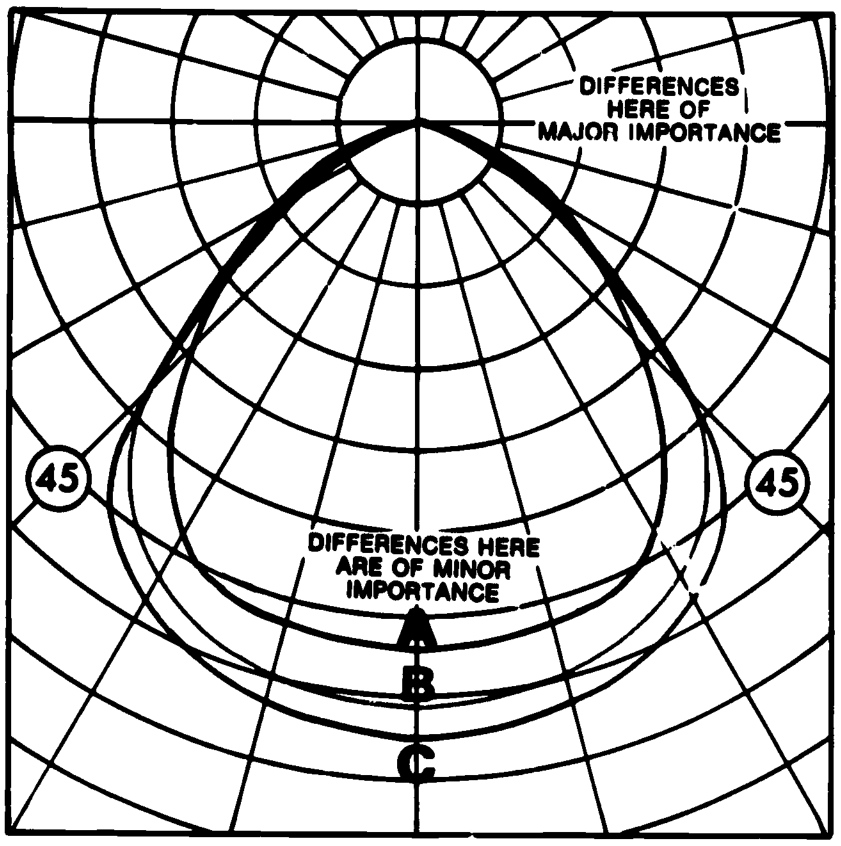


FIGURE 2 "Or Equal" photometric curves, A, B, and C, of Figure 1, superimposed to show the region of small differences of very great importance.

light needed, on a minimum basis is 38% more than System C. As this "plus" light must have no anti-footcandles *it would require a separate electrical system of local lighting, which could cost at least 50% more.*

(Continued on back page)

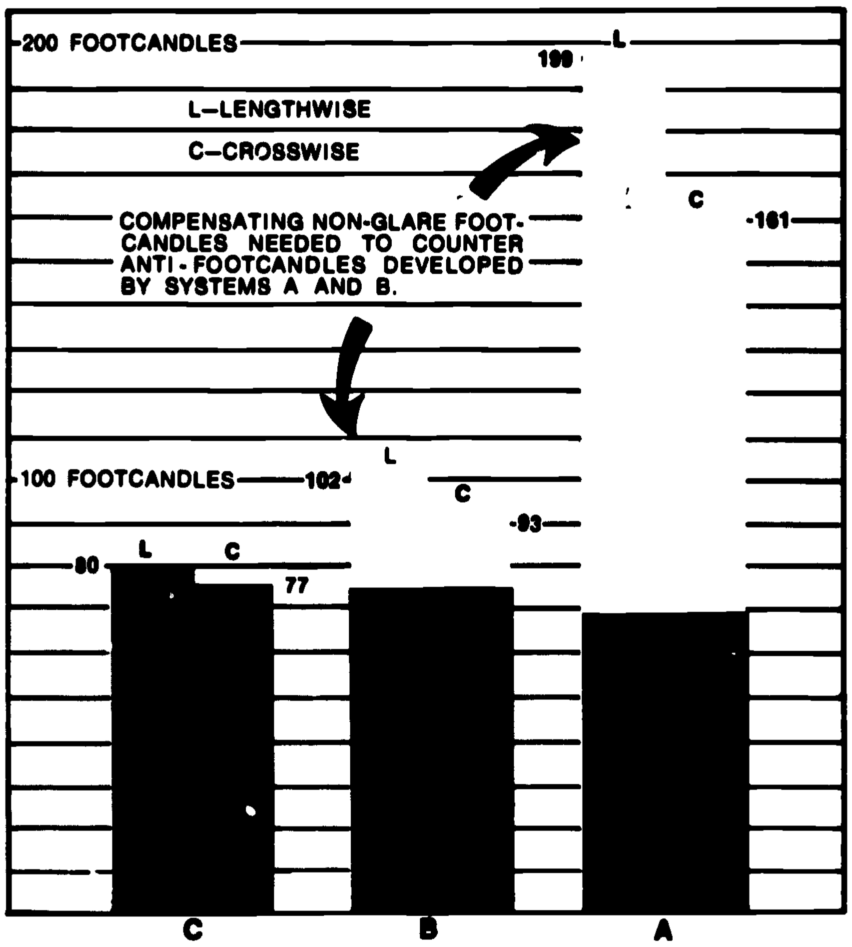
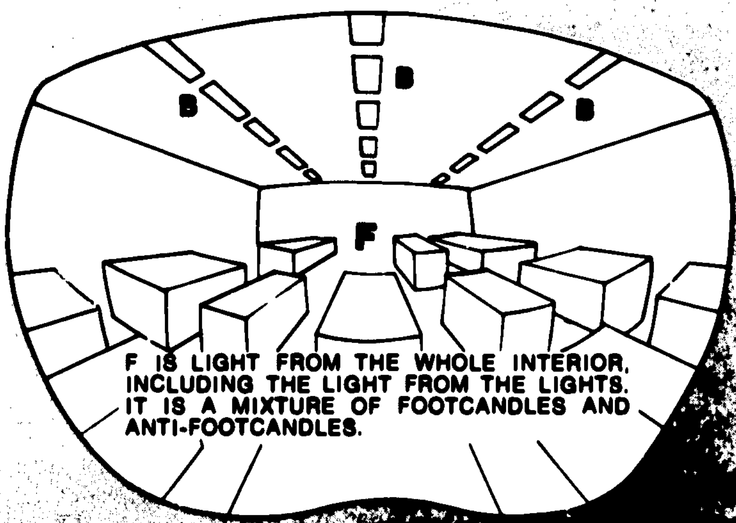


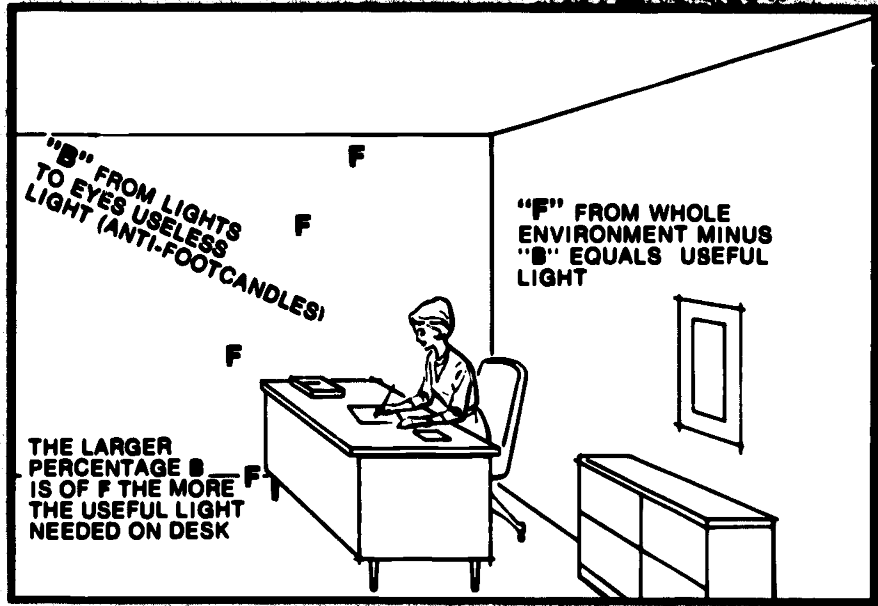
FIGURE 3 The effects of the anti-footcandles of the direct glare component, of the "Or Equal" Systems A and B, compared to C; in terms of the compensating footcandles needed: for both viewing directions.

HYPERFINE DIFFERENCES

The degree to which hyperfine differences can affect the human system is fantastic. The Press has lately carried many articles on the chemical energy effects of the drug "LSD". One-millionth of an ounce can so affect the chemical balance of the brain as to cause permanent insanity. Likewise, a frequency difference between different rays of light as small as a few-millionths of a second can not only change the response of the user, but can either initiate the release, increase the rate of release, slow down, or stop, the release of hormones."

Modern research has disclosed that very small differences in the ray structure of the light, their directions and intensity*, can make large differences to the response of the light-user. These differences can affect information recovery, comfort, safety, and even health.





POSITION OF OBSERVER

When two or more lighting systems have the same positions of lighting units (P), and the same size (Q), the least glaring system will have the highest "F" (footcandles measured vertically at the [illegible]) [illegible] "B" (brightness of lighting units toward observer). [illegible] can make large differences to people, as [illegible]

*See Architectural [illegible]

COST OF ANTI-FOOTCANDLES

On the assumption that this "plus" light would only cost the same per footcandle as the original light, the cost of "de-glaring" system B would be 38% to 50% more of the cost of the wiring system, lamps, lighting fixtures and installation.

Therefore, as in the case of the standard classroom shown in Figure 1,* based on compensating footcandles, the cost to own and operate System B per year, would be in the range of $210 to $224, while System C would cost $102. *THE TRUE VALUE DIFFERENCE* between these "or equal" systems is between $108 and $122 per classroom per year, despite the fact that a price difference of 23% per fixture was included, in favor of System B!

The price difference occurs once. The value difference occurs every year!

SYSTEM A VERSUS C

System A versus C requires $\frac{199}{69}$ = 289%, or 189% more *footcandles than it delivers* to compensate for its visual "noise". This will seem fantastic to many, but as remarked earlier, "The degree to which hyperfine differences can affect the human system is fantastic".

The high economic cost of this, compared to System C, which, with its relatively low visual "noise" does the job with 80 footcandles, is obvious.

FEWER LAMPS

So far we have discussed a way of evaluating competitive lighting systems by finding the additional glare-free footcandles needed to "de-glare" the more glaring systems to the level of the least glaring.

Another way is to drop the footcandle level the amount needed by reducing the number of lamps used.

Applying this to *System B compared to C*, we must reduce the M (or glare) value for B to that of C. (Please refer to formula on page 2).

M_B = 495, and M_C = 410. Therefore M_C is 83% of M_B, so, to have the same glare, System B must be limited to 83% as much light as it delivers, or 61 footcandles. That is, the maximum lighting level System B could be permitted, to give the same visual comfort as System C gives at 80 footcandles, is 61 footcandles.

Obviously, System B could not then meet the specification requirement of 70 footcandles, maintained in service, which System C easily meets.

The comparison between *System A and C* is that as total M for System C is only 57% of System A, this system could only be permitted 39 footcandles against 80 for System C, for the same degree of visual comfort.

FEWER FIXTURES

There is a third way to evaluate the relative merits of lighting systems offered as "equal". This is to find the number of lighting units which can be permitted the more glaring systems, so that their system glare is reduced to that of the least glaring system. This is a little more complicated because glare does not decrease equally as the number of lighting units in the same space is reduced, so we will only give the results here:

SYSTEM A	6 UNITS
SYSTEM B	10 UNITS
SYSTEM C (the standard)	15 UNITS

CONCLUSION

The preceding data shows that when the effects of anti-footcandles are evaluated, the "or equal" systems A and B are either much more costly than C on a true value basis, or cannot come even close to meeting classroom or office lighting level needs, when equalized by reducing lamps or fixtures.

*Of supplement.

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